Air quality monitoring, emission inventory and source apportionment study for Indian cities

Creating Innovative Solutions for a Sustainable Future

CASE STUDY :

BANGALORE SOURCE APPORTIONMENT

Earth Science and Climate Change Division,

TERI, New Delhi, INDIA

Background

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Non attainment cities and towns in India - Particulate matter

Air quality environment IMPROVEMENTS:

- Identification and Quantification of emission sources
- Prioritizing of sources
- Evaluation of control options with regard to techno-economic and administrative/regulatory feasibility and viability
- Formulation and implementation of city specific and National action plans

Viewing above

Follow up to the Auto Fuel Policy Report-2003

World-wide-Source Apportionment techniques -Urban air quality management

Study taken in six cities viz., Bangalore, Chennai, Delhi, Kanpur, Mumbai and Pune (2004 to 2011)

TERI - Bangalore

Objectives

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To profile Ground Level Concentration (GLC) of air pollutants in different parts of the Bangalore city including background, residential, commercial/mixed areas and source specific “hot spots” viz. kerbside/roadside, industrial zones, etc.

To prepare inventory for different air pollutants, their emission rates and pollution loads from various sources along with spatial and temporal distribution in Bangalore.

To apportion the sources of PM_{10} and $PM_{2.5}$ (limited) and prioritize the source categories for evolving Bangalore-specific air pollution management strategies/plan.

To assess the impact of sources on ambient air quality under different management/ interventions/control options and draw a roadmap of short and long term measures as considered appropriate and cost effective to ensure *“cleaner air in Bangalore”*.

Study Framework

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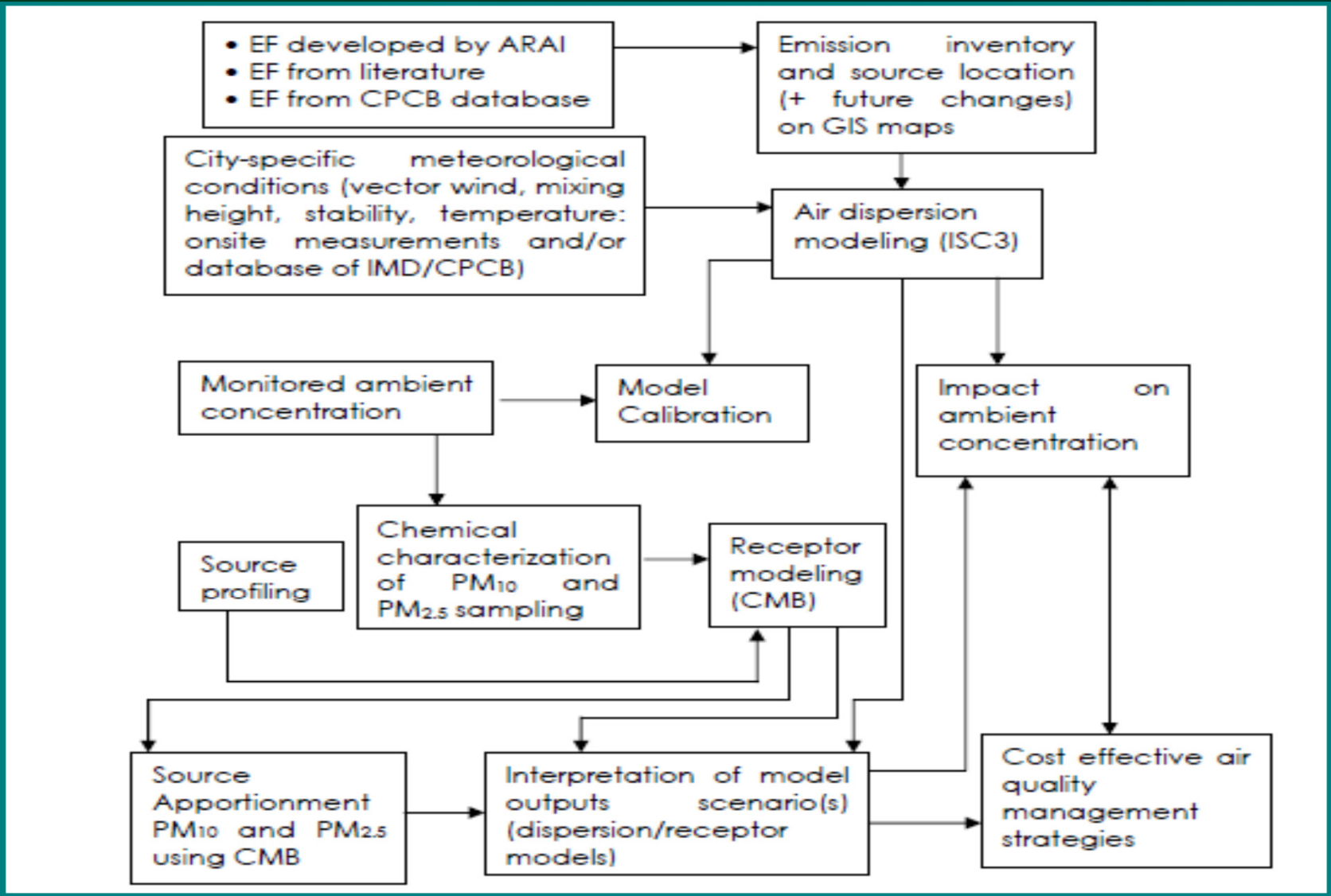

Characteristics of Bangalore city

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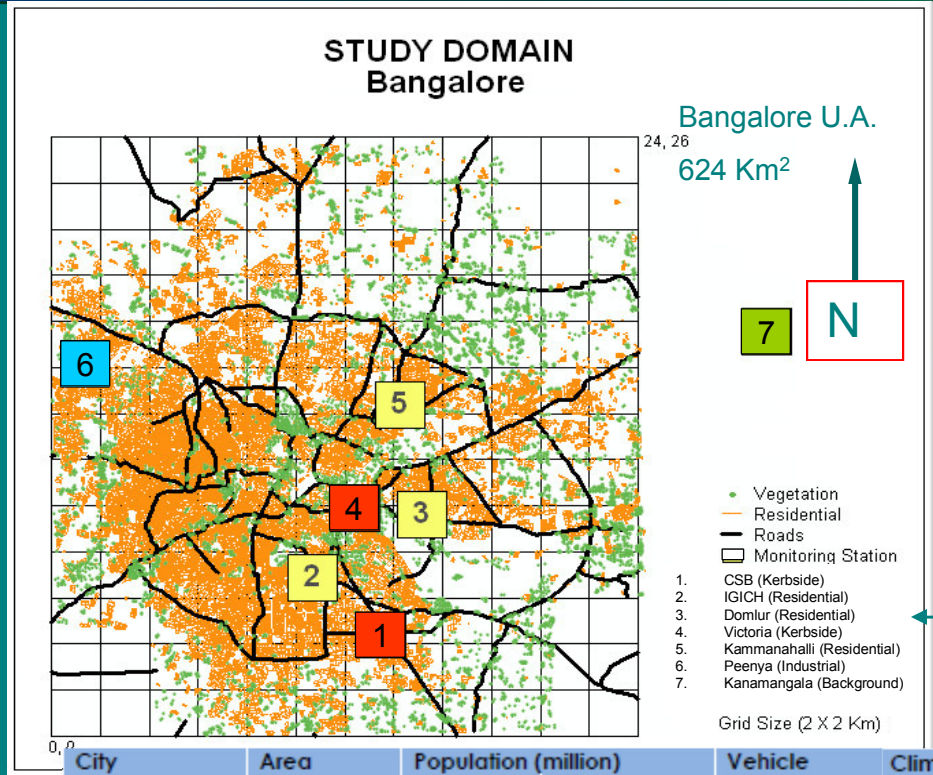

City	Area (Km²)	Population (million) 2001 Census	Population (million) Projected for 2011	Vehicle population 2007 (million)*	Climate	Remarks (including Socio-economic Activities)
Bangalore	565	5.7	7.6	2.53	• Pleasant climate throughout the year. • Max. Temp: 25-34°C, Min. Temp: 15-21°C. • Receives rainfall from both the northeast and the southwest monsoons. The wettest months are September and October. • Avg. rainfall: 970 mm/yr	Bangalore is commonly known as the Silicon Valley of India because of its pre-eminent position as the nation's leading IT employer. It is home to innumerous software companies, well-recognized colleges and research institutions, aerospace, telecommunications, and defence organizations

Profiling of seven sites

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STUDY AREAS

Site	Site Description	Predominant activity levels
Domlur	Residential	-High and medium income category population -Vehicular distribution shows 47% 2-wheelers, 34% cars, 16% auto-rickshaws and 3% heavy vehicles.
Kammanahalli	Residential	-Low and medium income category population -Vehicular distribution shows 57% 2-wheelers, 18% cars, 20% auto-rickshaws and 5% heavy vehicles.
Victoria Road	Kerbside	-Medium and low income category population -Vehicular distribution shows 47% 2-wheelers, 29% cars, 19% auto-rickshaws and 5% heavy vehicles.
CSB	Kerbside	-Mixed Population of all income groups -High volume of heavy-duty diesel (HDD) vehicles - Vehicular distribution shows 46% 2-wheelers, 27% cars, 13% auto-rickshaws and 14% heavy vehicles.
IGICH	Hospital	-Mixed Population of all income groups -Vehicular distribution shows 53% 2-wheelers, 22% cars, 19% auto-rickshaws and 6% heavy vehicles.
Peenya	Industrial	-Only one residential colony with medium and low income group population -High volume of heavy-duty diesel (HDD) vehicles - Vehicular distribution shows 57% 2-wheelers, 14% cars, 11% auto-rickshaws and 18% heavy vehicles.
Kanamangala, Whitefield	Background	-Plantation in 70% area of zone of influence -Movements of tractors and plying of very few public transport buses and HDD vehicles.

Ambient Air Quality Monitoring Network Design

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Under common methodology, in order to address all the expected anthropogenic emission sources (including secondary pollutants) prevailing in Bangalore, monitoring of criteria as well as non-criteria pollutants were included.

Particulars	Pollutants						
	SPM	PM_{10}/RPM	SO_2	NO_2	$PM_{2.5}$	CO	VOC
Equipment	High Volume Sampler	Multi-speciation sampler/ Respirable dust sampler (RDS)	Impingers attached to HVS/RDS	Impingers attached to HVS/RDS	FRM sampler	Automatic Analyzer	VOC Sampler
Sampling period	8/24 hrly	8/24 hrly	8/24 hrly	8/24 hrly	8/24 hrly	4/24 hrly/continuous	4/8/24 hrly
Sampling frequency	20/30 days continuous in each of the three seasons	20/30 days continuous in each of the three seasons	20/30 days continuous in each of the three seasons	20/30 days continuous in each of the three seasons	one week continuous in each of the three seasons	one week continuous in each of the three seasons	once in each of the three seasons

This provided insight to air quality issues including contribution from various sources and extent of presence of secondary pollutants.

The air quality sampling was conducted for three seasons: summer, pre monsoon and winter.

The PM_{10} as well as $PM_{2.5}$ samples were collected on different filter media to make detailed analysis of constituent fractions including tracer elements and molecular markers.

Ambient air was characterized for SPM, PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, O_3, Formaldehyde, VOCs (Benzene, 1-3 Butadine) OC, EC, Ions (11), Elements(36), Benzene, PAHs and molecular markers(11).

Instrumentation at site

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Three Seasons Average (PM & Gaseous pollutants)

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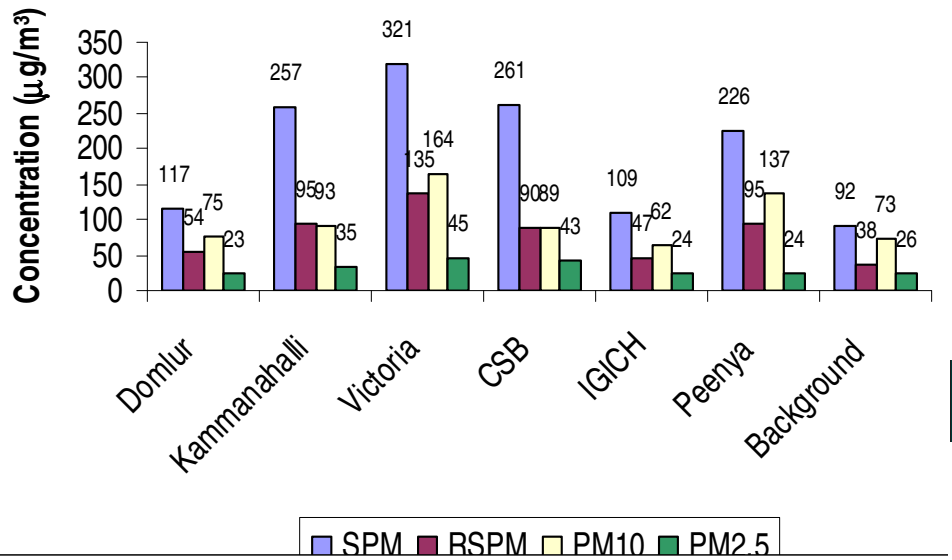

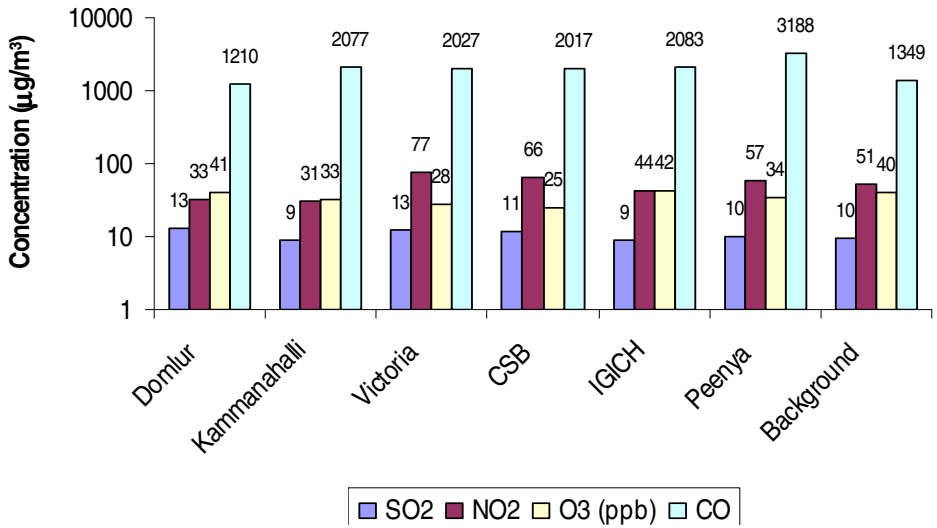

SPM, RSPM levels highest at Traffic (Victoria Rd. & CSB) and Industrial (Peenya) Also, one of the residential location (Kammanahali) shows high values.

$PM_{2.5}$ values are higher at traffic locations

Annual NOx standards are violated at Traffic location (but remain under 24-hourly std.)

SO_2 remains within the limits (both annual and 24 hrly) at all locations

CO concentrations violate the limits (8h) at all locations except Background

Residential O_3 levels are within the standards at all the locations (std. 8hr: 90 µg/m³ = 46 ppb)

Mass distribution of chemical species in PM_{10} and $PM_{2.5}$ samples : Three seasons average

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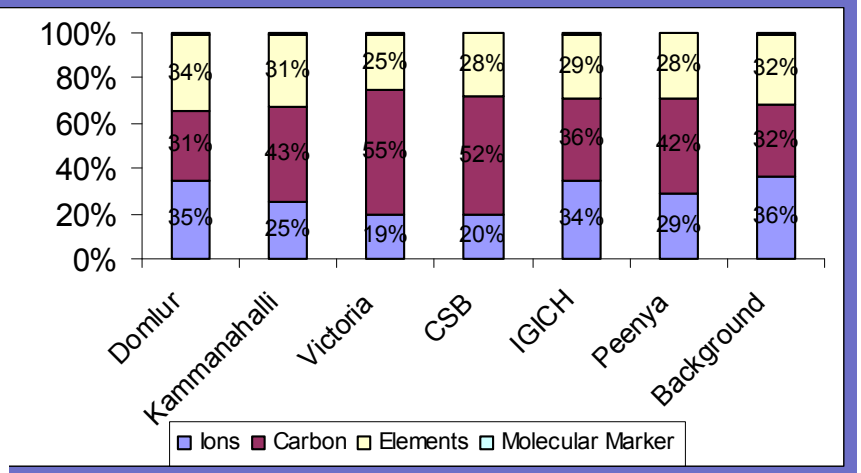
Carbon content highest at kerbside and lowest at background & Domlur (residential) locations

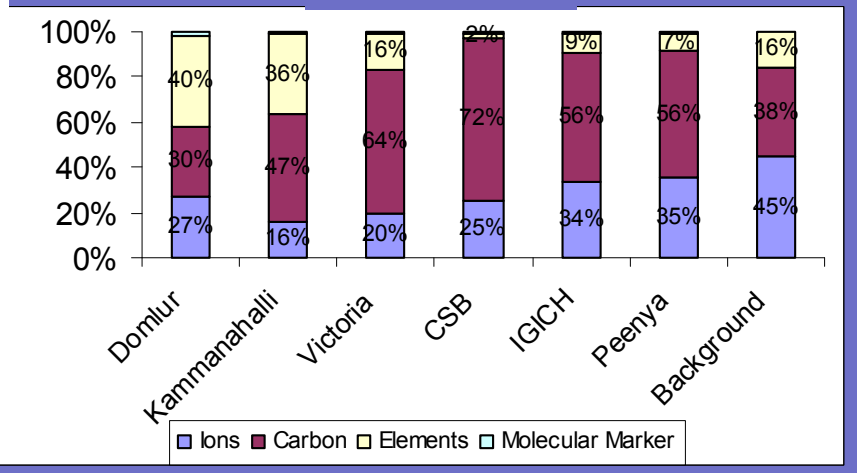
Ionic content maximum at background - shows enhanced contribution by secondary particulates

Share of elements decreases at most of the locations in the case of $PM_{2.5}$ as compared to PM_{10}; probably depicts lesser influence of coarser elements

Kerbside locations show significant increase in carbon content in $PM_{2.5}$ as compared to PM_{10} indicating enhanced contribution in the finer particle range by sources such as vehicles



PM10



PM2.5

Factor Analysis- Source Identification

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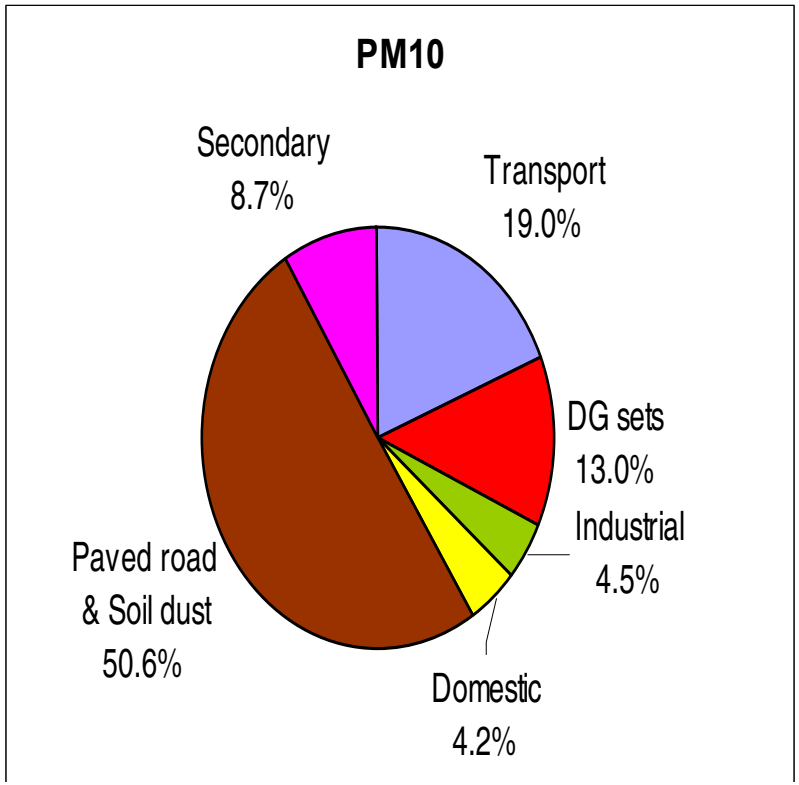
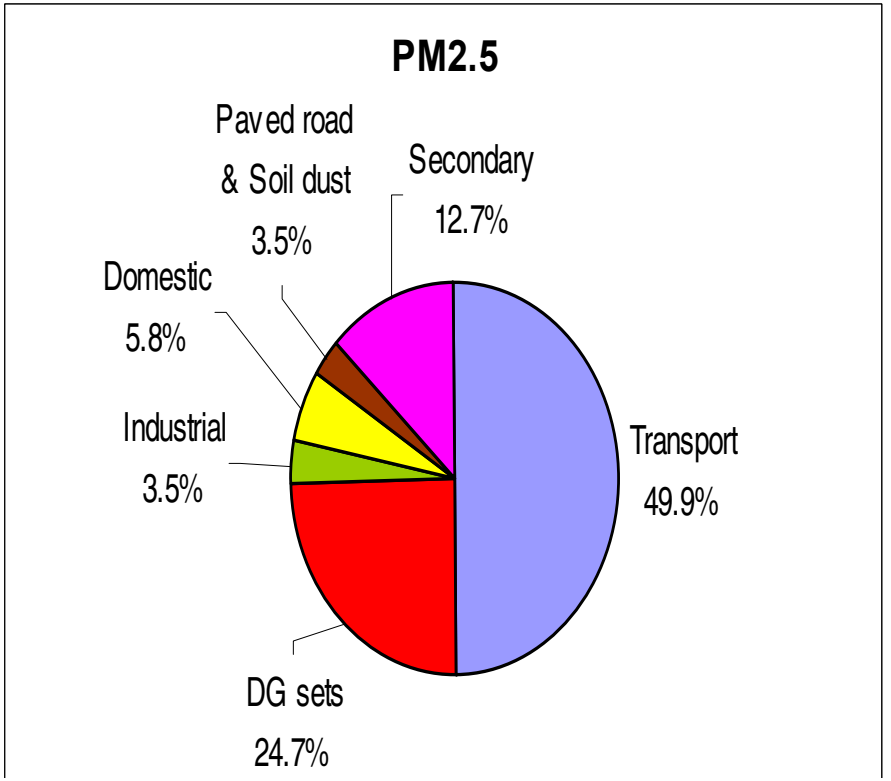
S. No.	*Site*	*Site description*	*Indicative sources*
1	Silk Board	Traffic	Motor vehicle exhaust, secondary particulate matter, construction activities, natural soil, road dust
2	Victoria road	Traffic	Motor vehicle exhaust, natural soil, road dust, biomass burning, secondary particle formation
3	Peenya	Industrial	Road dust, residual oil burning, crustal soil dust, industrial sources, metal industries, motor vehicle exhaust, construction activities
4	Domlur	Residential	Soil and road dust, secondary particle formation, motor vehicle exhaust, storm water drain, biomass burning
5	Kammanahalli	Residential	Road dust, coal combustion, vegetative burning, secondary particle formation, resuspended soil, motor vehicle exhaust
6	IGICH	Hospital/ Residential	Road dust, natural soil, secondary particle formation, construction activities, motor vehicle exhaust, incinerator combustion
7	Kanamangala/ Background	Background	Natural soil, crustal source, road dust, vehicular sources, biomass burning, secondary particle formation

Overall: vehicle exhaust, road dust, secondary particulates, construction activities, biomass burning

CMB- Source Quantification





Share of transport sector increases from 19% in PM_{10} to 50% in $PM_{2.5}$
Share of anthropogenic sources eclipsed by dust contributions in case of PM_{10}
DG sets :important source. Contribution is 13% & 25% in PM_{10} and $PM_{2.5}$.
Contribution of industries to the particulate matter is low.
Domestic sector also has a small contribution in both PM_{10} and $PM_{2.5}$.
Share of secondary particulates is higher in $PM_{2.5}$ than in PM_{10}, depicting their finer size

Emission inventory – city level (2007)

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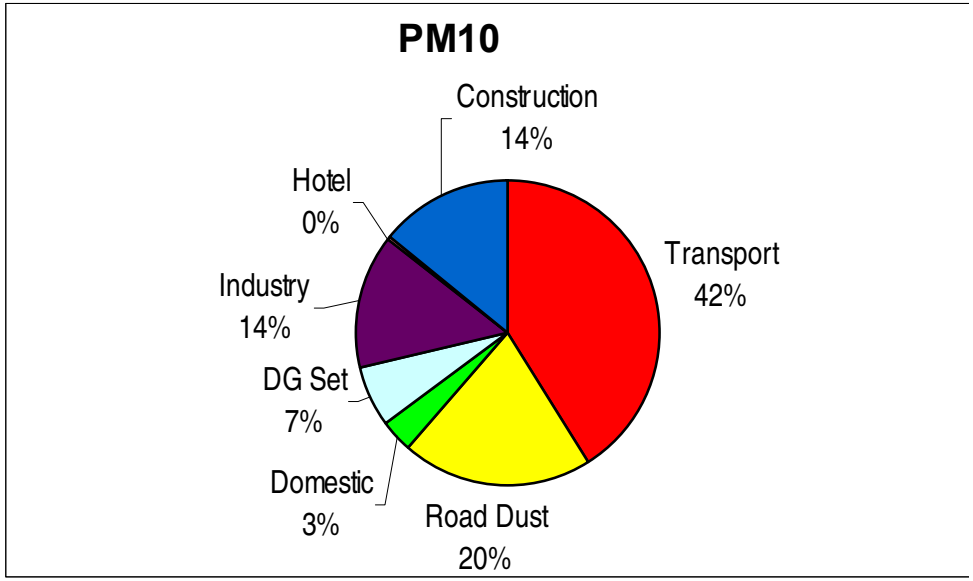
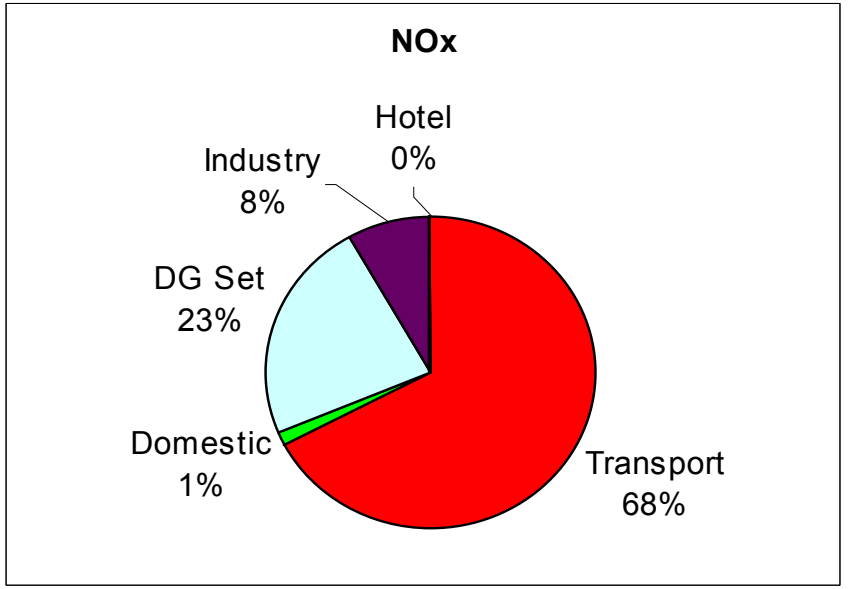
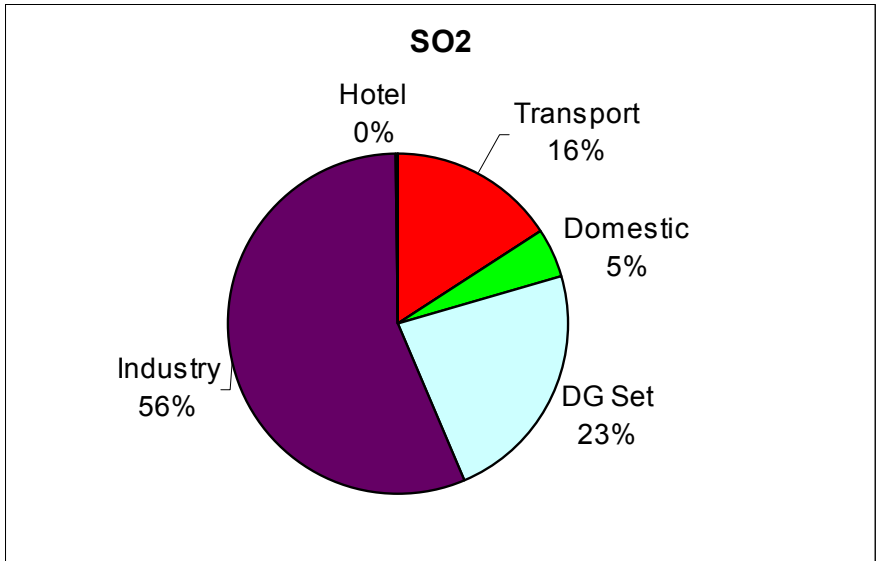


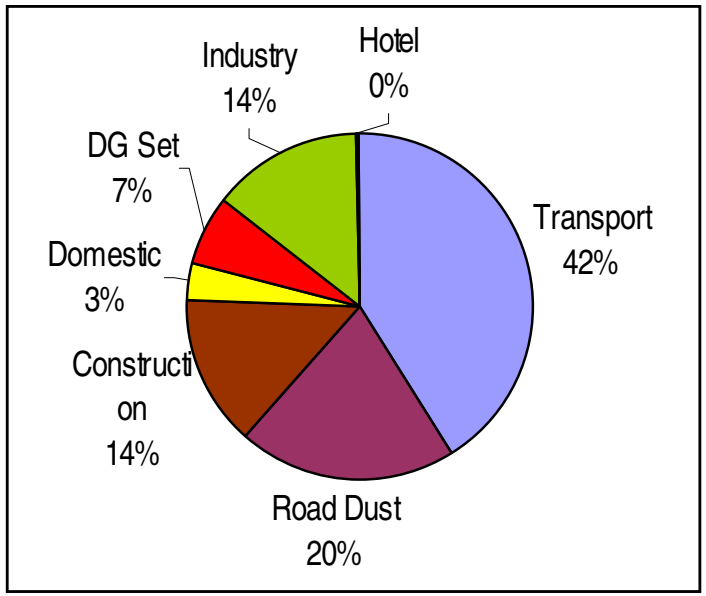




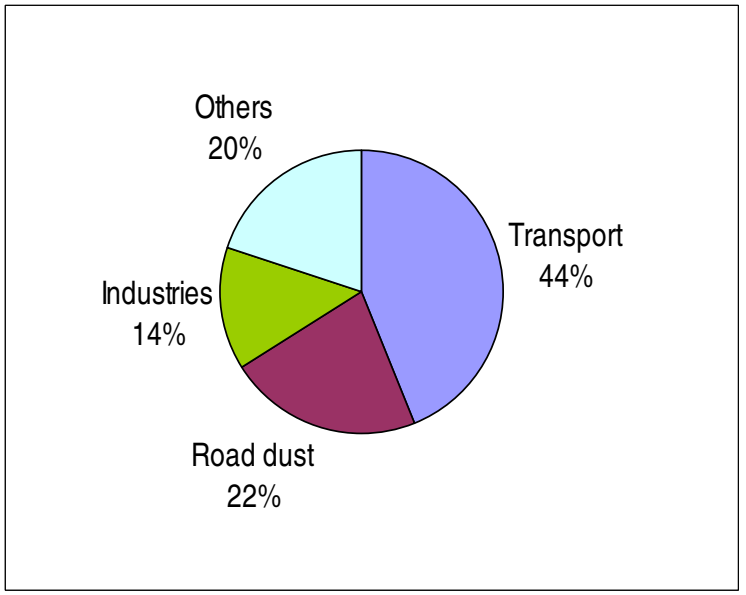
Total pollution load

- PM10 - 54.4 T/d
- NOX – 217.4 T/d
- SO2 – 14.6 T/d

Source contribution based on emission inventory, dispersion modelling & receptor modelling approach (PM_{10}; 2007)

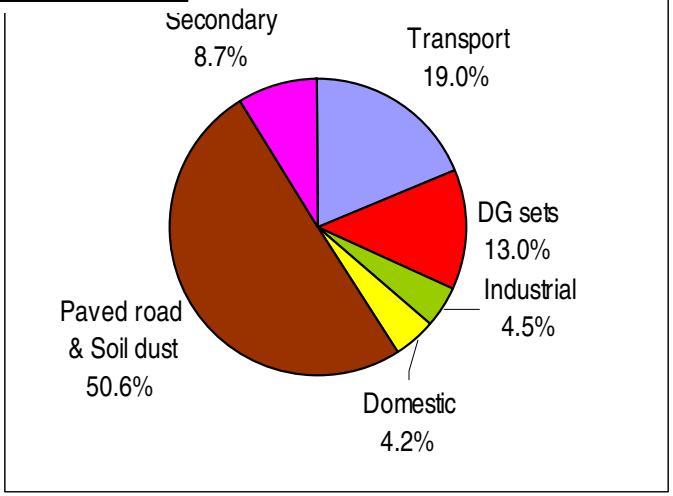


Emission Inventory
(all season)



Dispersion Modelling
(winter season)

PM10



Receptor Modelling (all season)

Alternate scenario description : Estimated emission load for PM_{10} and NOx under the BAU and Alternate scenarios

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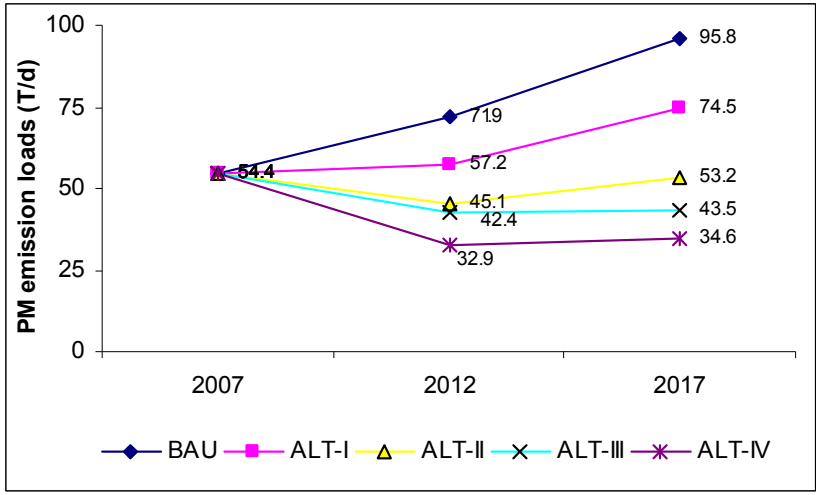
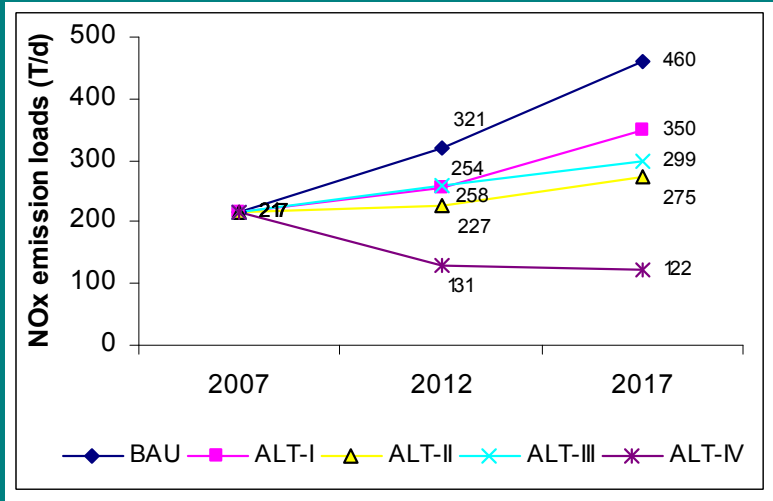
Sectors	Alternate-I	Alternate-II	Alternate-III	Alternate-IV
Transport Industries DG sets Road dust re-suspension Construction	Scenario with **certain strategies** to reduce the air pollution loads across various sectors.	**Stringent scenario with many more strategies** to reduce the air pollution load across various sectors as compared to Alternate- I scenario.	Scenario that contains **additional set of measures** that are not a part of the common control options as per the chart suggested by CPCB (for example, introduction of **fuel efficiency standards, installation of control devices (DOC/DPF) on all diesel vehicles and DG sets**).	**Scenario with measures that are more oriented towards meeting the air quality standards in future**





%PM reduction w.r.t. BAU

Scenario	2012	2017
ALT-I	-20%	-22%
ALT-II	-37%	-44%
ALT-III	-41%	-55%
ALT-IV	-54%	-64%

% NOx reduction wrt BAU

Scenario	2012	2017
ALT-I	-21%	-24%
ALT-II	-29%	-40%
ALT-III	-20%	-35%
ALT-IV	-59%	-73%

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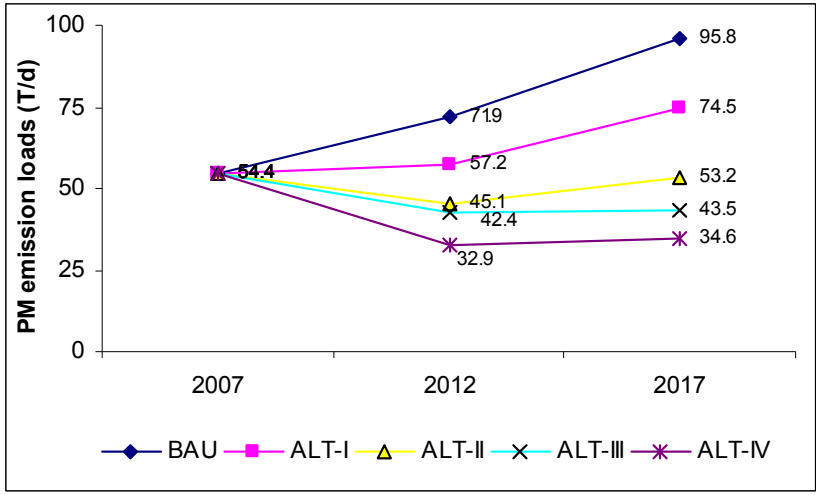

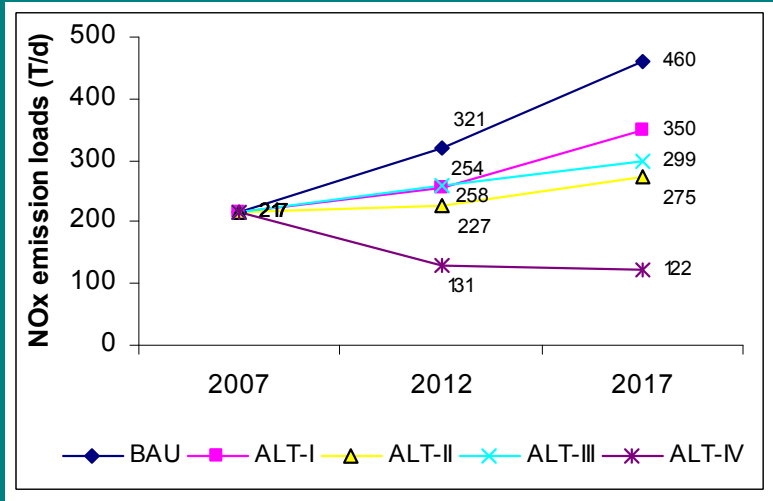

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Contours for 24-hourly average PM_{10} concentration ($\mu g/m^3$) for BAU & alternate scenarios

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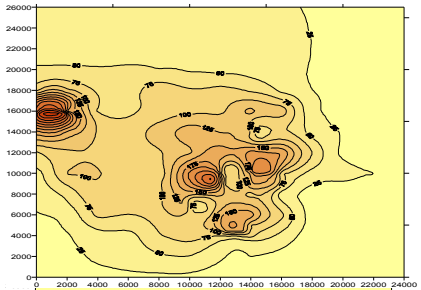
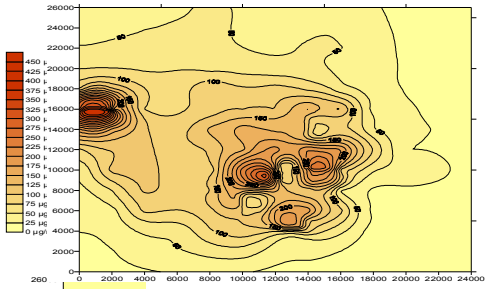
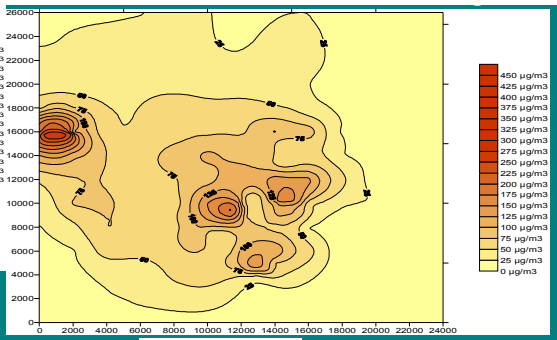
- Alternate scenarios show a significant decrease compared to BAU scenario (both in 2012 & 2017)
- Alt. IV scenario, has maximum reduction and broadly all areas across the city conform to the ambient AQ standards in 2012 and 2017



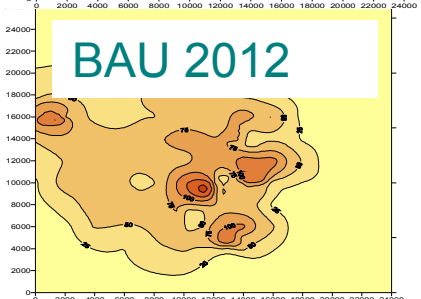
BAU 2012



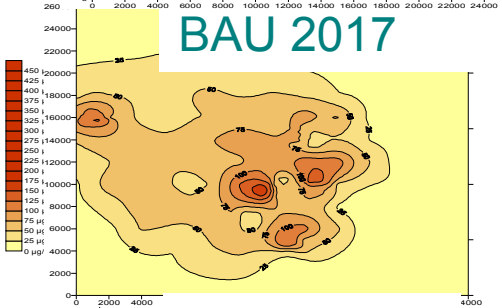
BAU 2017



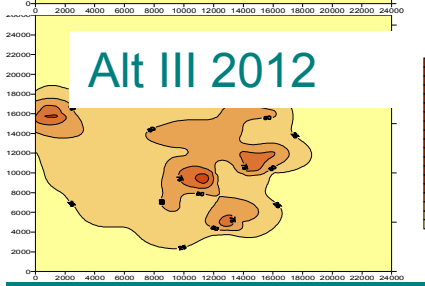
BAU 2007



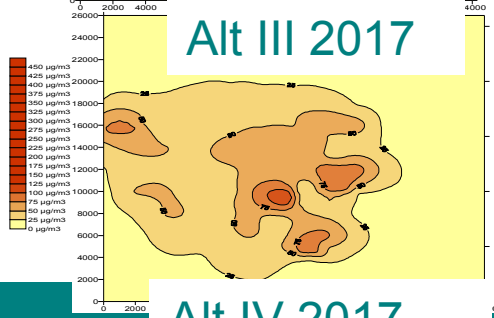
Alt III 2012



Alt III 2017



Alt IV 2012



Alt IV 2017

Contours for 24-hourly average NO_x concentration (µg/m³) for BAU & Alternate scenarios

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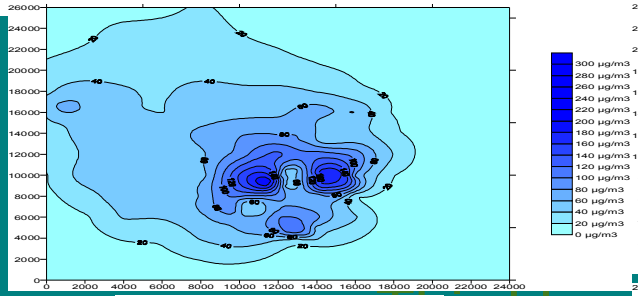
- Alternate scenarios show a significant decrease compared to BAU scenario (both in 2012 & 2017)
- Alt. IV scenario, has maximum reduction and all the areas in the study domain comply against the residential area standards



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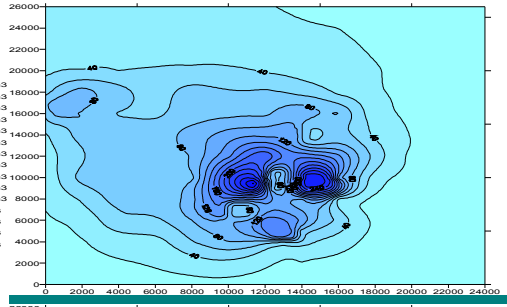
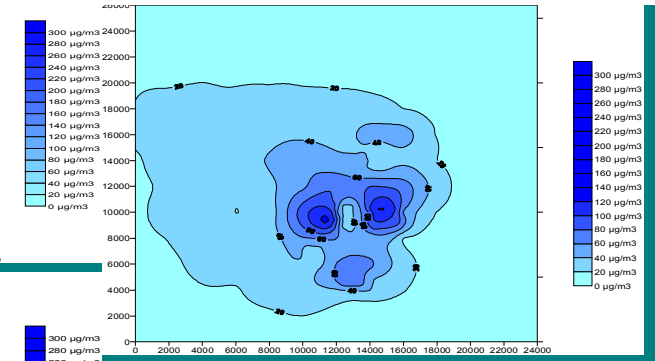


BAU 2017



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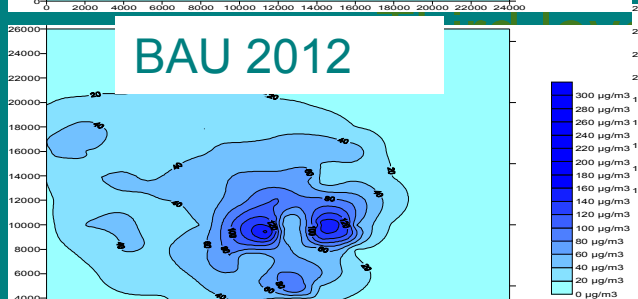

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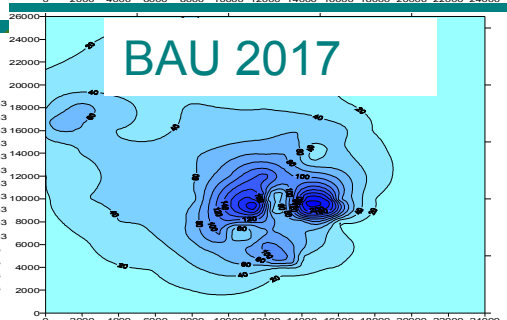
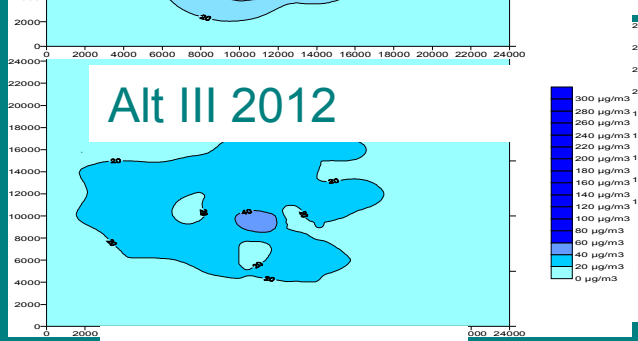
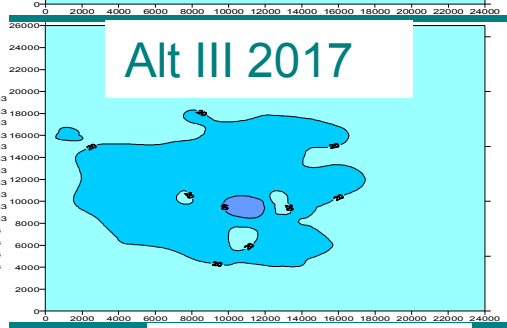


Alt III 2017



Alt IV 2012



Alt IV 2017

Prioritised list of key interventions in terms of reduction in total PM_{10} emission loads in 2017

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S.No	Strategy	% reduction in total PM_{10} emission loads in 2017
1	By-passing of trucks around Bangalore	13.8%
2	Installation of DOC and DPF devices in all pre-2010 diesel vehicles	13.0%
3	No power cuts leading to zero usage of DG sets	12.8%
4	Ban on 10 year old commercial vehicles in 2012 and 2017	12.5%
5	Ban on any new industries in city limits(6.2%) and fuel shift towards cleaner fuel NG (5.3%) in existing industries	11.5 %
6	Installation of DOC and DPF devices in DG sets	8.3%
7	Wall to wall paving for reduction of road dust	6.2%
8	Better construction practices	5.5%
9	Conversion of public transport (commercial 3 & 4 w) to CNG (25% in 2012 and 100 % in 2017)	4.0%
10	Improvement in inspection and maintenance for vehicles	2.5%
11	Inspection and maintenance for DG sets	1.9%
12	Enhancement of public transport system based on CNG (shift of PKT from private vehicles to public transport i.e. 10% in 2012 and 20% in 2017)	1.7%
13	Enhancement of public transport system based on diesel (shift of PKT from private	1.5%

Key insights

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Air Quality

- Particulate matter of prime concern and NOX concentrations also of concern especially at kerbside.

Emissions of pollutants

- Both PM_{10} and NO_X show a doubling over the next decade.

Major contributors

- PM : Transport, Road dust/construction, industry; NO_X: Transport, DG sets

Action plan

Multiple interventions required across various sectors in order to meet air quality standards in future. An action plan suggested in terms of control strategies, impact, responsible agencies, and time frame.

Achievement

Comprehensive AQ study for Bangalore city incorporating aspects related to monitoring, chemical characterisation, emission inventory, dispersion and receptor modelling – for apportionment of PM sources and development of an air quality management plan.

Way forward

Further Improvement in methodology, focus on fine PM mass and number, epidemiological PM health studies, replication in other urban cities and regional background stations

Actions taken in Bangalore

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- ✓ Most of roads converted to one way route
- ✓ Bypassing of HDDV form the city center

Other actions taken were:

- ✓ Metro rail
- ✓ CNG as an alternate fuel

THANK YOU